A CHEBYSHEV LOW PASS FILTER FOR 6M

D. Bowman describes a seven element filter for reducing harmonic emission

Radio amateurs have always been aware of the problems associated with the generation and radiation of harmonic energy. With the allocation of 50MHz in this country it is worthwhile considering the special problems posed by the emission of harmonics from a transmitter operating on the new band.

On the lower HF bands most of the unwanted harmonic energy will be produced on frequencies already allocated to the amateur service. For example, the second, third and fourth harmonics of a 40m transmitter will fall in the 20, 15 and 10m amateur allocations. Other harmonics eg, the 2nd harmonic of 80m transmissions above 3·550MHz fall into areas allocated for international broadcasting. The high power levels used for these services considerably reduce the practical risk of interference, although it should be remembered that low level outputs of a few hundred milliwatts ERP can cause interference in the immediate locality even if the service is being provided by a 250kW broadcast transmitter.

Unfortunately the harmonic energy produced by 50MHz amateur transmissions falls into areas of the radio spectrum where the potential for serious interference is much greater than on any of the lower bands. The greatest danger is interference to the users of 100·0 to 104·0MHz from second harmonic radiation. At present 100 to 102MHz is allocated to the emergency services and the consequences of any interference here are obvious. 102 to 104MHz currently provides an extension for band 2 radio broadcasting while over the next three years the present emergency service users will be relocated on higher VHF frequencies and their place taken by radio broadcasting. For a number of years the government has been proposing the introduction of a third tier of broadcasting namely 'community radio,' the first of these stations being due to become operational in mid-1989. If these low power broadcasters, or even conventional IBA and BBC stations are licensed to use these frequencies it will no longer be the case that harmonic radiation will go unnoticed.

Indeed we must face the possibility of amateurs in urban areas having hundreds of people within a small radius of their QTH all tuned in to the amateur's second harmonic! There would seem to be a case for ensuring radiated harmonic energy is reduced to the lowest achievable level. Extra filtering between the final amplifier and the antenna would be a sensible preventive measure for all 50MHz operators to consider.

FILTER OPTIONS

There are a number of solutions to the problem of harmonic filtering for the six metre band. Bandpass filters using quarter wavelength striplines as described by the ARRL[1] are very effective, offering good rejection of harmonic and spurious outputs above and below the required frequency. The disadvantage is that the high *Q* factor inherent in the design necessitates constant retuning over a band as wide as 50MHz. Alternatives to the bandpass approach include notch and low pass filters and a notch filter design using resonant lengths of coaxial cable has previously been presented by G4TUZ in Technical Topics[2]. This technique reduces even order harmonic radiation (2nd, 4th, 6th, etc.) and probably represents the most cost-effective means of achieving a 30dB reduction in 2nd harmonic energy. Readers are referred to G4TUZ's article for further details.

A third possibility is to design a low pass filter which will provide a high level of attenuation to signals above a certain cut-off frequency – and this will be the approach taken here. The filter is a seven element Chebyshev low pass type in a pi configuration and the theoretical response is given below.

Assuming a passband ripple of 0·01dB

Passband ripple 0·01dB (input VSWR = 1·1:1)		
Harmonic attenuation	2nd	−47dB
	3rd	−74dB
	4th	−93dB
	5th	−107dB

The rejection figures are dB relative to the designed cut-off frequency of the filter.

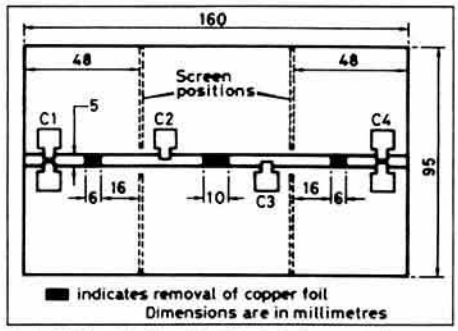

Fig 1. PCB layout. The copper laminate is removed from the shaded areas and the inductors are mounted across the resulting gaps.

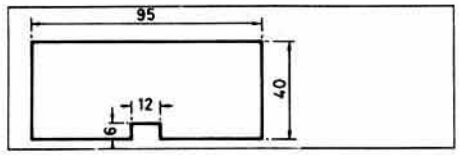

Fig 2. Internal screens. Both screens are mounted centrally around the raised PCB strip and soldered to the ground plane on both sides along their entire length.

In practice the performance is limited by several factors. First, the cut-off frequency has to be somewhat higher than the highest frequency in use so as to allow for errors due to component tolerances and variation in the physical layout of the circuit. Second, the ultimate rejection will be limited to 60-70dB due to stray radiation between individual sections of the filter. Allowing for these limitations, we can still design an easily constructed filter with a predictable performance and this unit has been designed with both component availability and high performance as primary objectives. The cost of components purchased new from retail suppliers is approximately £16.

CONSTRUCTION

The circuit is built on a piece of Eurocard sized (160×100m) single-sided copper laminate. A strip 4-5mm wide is cut from the longest side and glued longitudinally to the centre of the copper laminate with cyanoacrylate (superglue) adhesive – see Fig 1. Three sections of copper have to be removed from this strip. This is best accomplished by cutting through the copper at the required points with a small knife and then heating the unwanted section with a soldering iron, allowing the copper to be lifted away without causing damage to the fibreglass base.

The screens (see Fig 2) can be made from either tin-plate or double-sided copper laminate and these are soldered to the board in the positions shown. The components can be fitted in any order, and the completed board mounted in the base of a diecast box using three 4BA nuts and bolts. Input and output connections are made via SO239 sockets, the lower two mounting holes of which are fitted with 4BA solder tags. These are bent at right angles and soldered directly to the groundplane of the board.

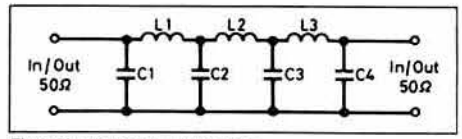

Fig 3. Circuit diagram of the filter.

PERFORMANCE

Purists may object to such crudities as glueing strips of PCB material to a groundplane. However, not only is this a perfectly acceptable breadboarding technique but in this particular circuit it proved superior to a purpose etched PCB. This is because it ensures an even distribution of earth currents throughout the surface of the whole board and conveniently provides exactly the correct height for mounting the cased mica capacitors.

The filter cut-off frequency has been adjusted to 60MHz and although this may appear a little high, it was found during testing that this coincided with minimum insertion loss between 50-52MHz. The response curve was plotted using a Telonic Instruments swept frequency generator and was found to give a textbook response, essentially flat to 58MHz with cut-off occurring at 60MHz. Beyond 60MHz a high level of attenuation was observed up to a frequency of 550MHz, which was the limit of the test equipment used. Attenuation at 100MHz ▷

was measured as better than 35dB, while at 150MHz it was approximately −50dB relative to a 50MHz fundamental.

The Semco capacitors are rated at 350V and should be used in preference to silvered mica – plate ceramic should not be used. The power handling capability of the circuit is limited by the thin strip of PCB material. This will not be a problem for UK amateurs reproducing the circuit. However, in countries where higher powers are permitted, constructors should ensure that resistive losses are kept to a minimum by covering the entire length of the PCs strip with a layer of solder.

COMPONENTS LIST

CAPACITORS
C1,4 44p (2 × 22p in parallel) 350V cased mica
C2,3 100p 350V cased mica
Capacitors available from Cirket Ltd, Broxbourne, Herts.

INDUCTORS
L1,3 4 turns 16SWG tinned copper, 13mm ID, 10mm long with 5mm leads
L2 5 turns 16SWG tinned copper, 9.5mm ID, 12·5mm long with 5mm leads

GENERAL
PCB Eurocard 160×100mm, single-sided copper laminate on 1·6mm epoxy glass. RS Components Code 435-484

Box Diecast Aluminium, 171 × 121 × 55mm. RS Code 509-995
11 × 4BA nuts, bolts and washers
4 × solder tags
2 × SO239 sockets

TESTING AND INSTALLATION

Having completed the construction you will probably need to satisfy your curiosity and test the performance of the filter. Most amateurs will have access to a SWR bridge and 50ohm dummy load; these are the only two items required to perform a series of useful tests. First connect the dummy load to the filter, note that as the Chebyshev is a symmetrical design, either connector can be used as the 'output'. The SWR bridge is then inserted between the transmitter and the filter input and after ensuring all connectors are secure a few watts of RF is passed through the system. The VSWR should be less than 1·2:1 across the entire 6m allocation.

If you wish to confirm the filters low pass action, the test can be repeated using a 2m transmitter as a source of RF. In this case the VSWR will be extremely high as the filter will prevent the higher frequency energy reaching the 50ohm load. Only low power should be used for this test as the transmitter will be severely mismatched and full power may cause damage to the output devices. If you do not have a SWR bridge and 50ohm load then the filter can be checked by assessing its effect on received 6m and 2m signals. When you are satisfied that the filter is operating correctly it can be permanently installed in-line between the transceiver and the antenna.

The Author would like to thank the following for their assistance in the preparation of this article:- K R Renton, G6JMJ of Imperial College, London for performance evaluation. □

References
1 The *ARRL Handbook*, all recent editions.
2 'Coaxial stub filters reduce RFI from 50MHz transmitters' by Paul Boyd, G4TUZ, Technical Topics, October 1987, p750.

AN EXPERIMENTAL HF/MF LOOPSTICK ANTENNA

Richard Q Marris, G2BZQ, presents an antenna suitable for use on amateur bands with frequencies up to 9MHz

The integral loopstick or ferrite rod antenna has been with us for about three decades as an essential part of any domestic MW/LW receiver. However, much less well known is the fact that with careful selection of core materials, it is possible to design an antenna which is suitable for use on the HF amateur bands. In fact designs have been used at frequencies of up to 30MHz and a transmit loopstick has been used quite successfully at my station with a low power 80m CW transmitter. This may go somewhat against accepted opinion – but then all rules are there to be bent or broken!

In the light of previous experiments it was decided to design and produce an efficient experimental loopstick antenna, suitable for use with a typical general coverage receiver. To make such a device as operationally useful as possible (and consequently much more difficult to design!), it was decided that it should be capable of continuous tuning from 545kHz to 9MHz with absolutely no band switching involved. A further design requirement was that the coupling arrangement for the receiver's antenna input should be both low impedance and capable of covering the whole frequency range without switching or adjustment. Finally the antenna had to be sufficiently efficient to be useable with a high RF gain receiver without the need for further preamplification.

CIRCUIT DETAILS

The circuit shown in Fig 1, though simple, is somewhat unusual in consisting of a 190 x 13mm circular cross-section nickel-zinc ferrite rod*, and a three gang, 500pF per section air spaced variable capacitor. The ferrite rod offers a high Q at HF frequencies and in order to cover the desired range two separate tuned circuits are used. The combination of L1 and CV1 serves to cover 545kHz to 2.500MHz while L2,CV2 and CV3 cover 2.150 to 9.375MHz.

The variable capacitor (CV1,2,3) is a large air spaced component, chosen because of its low minimum capacitance compared with miniature types. Its physical size is acceptable in view of the ferrite rods large dimensions. Such three gang, 500pF per section capacitors can be purchased from manufacturers but can be much more economically obtained from old valve receivers. The one used in the prototype is plated brass and was taken from a derelict audio generator chassis originally purchased for only £1! The variable capacitor is prepared for use simply by cleaning it up as required and carefully removing any existing padding capacitors. It may also be necessary to shorten the drive shaft somewhat, in order to accommodate the slow motion drive.

The loopstick is coupled to the receiver by means of two series-wound coils L3 and L4; various other coupling methods were tried but this configuration was found to be the most effective, providing a satisfactory impedance match for either 50 or 70ohm systems. The choice of feeder depends upon the receiver input socketry, and may be RG58 coaxial cable or flat twin – there is nothing to choose between the two in terms of performance. Incidently, twin extension speaker lead is a good source of flat twin as it is both cheap and gives an excellent match.

CONSTRUCTION

Figs 3a,b,c show the construction used on the prototype. Individual designs will vary depending upon the size of the variable capacitor, but the general format should be followed. The three gang variable capacitor should be mounted in an inverted position as it was found during early experiments that there was a hiccup in the tuning on HF as the leading edge of the moving plates (CV2/CV3) reached their nearest point to L2. Such an arrangement also keeps the leads short.

Winding details and sizes for the ferrite rod and coil former assembly are quite critical and Figs 2a,b should be strictly adhered to. Plastic-coated Terry clips are mounted at either end of a piece of wood measuring 190 x 22 x 13mm and the 190 x 13mm diameter ferrite rod fits into these clips. A 75mm length of 16mm outside diameter plastic wall pipe is slipped over one end of the rod. This piping has a bore which is just sufficient to accommodate the ferrite rod and can be obtained from most DIY stores.

Coil winding details can be seen in Fig 2b. L1 is wound directly onto the rod with its ends held with superglue, after which L3 is wound over the centre of L1 and similarly affixed. L2 is wound onto the centre of the 16mm O/D tube, with its ends similarly secured and L4 is wound over the centre of L2. The link between L2 and L3 is taken through two drilled holes in the wood as shown in Fig 3b. The number of turns, wire types and dimensions for all coils are shown in the table. Finally, it is essential to remember that the rod and coil assembly should be mounted clear of any metalwork.

The 'chassis' of the loopstick antenna consists of a piece of single sided circuit board (copper up-

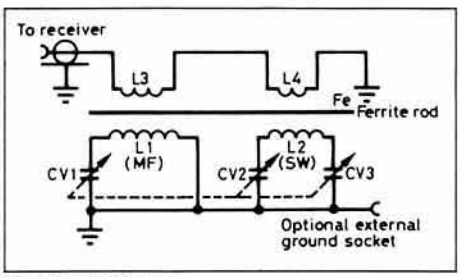

Fig 1. Circuit Diagram